

abstracts of the
international workshop

fire design of concrete structures

from materials modelling to
structural performance



University of Coimbra, Portugal | 8th and 9th November

07



Faculdade de Ciências e Tecnologia da
Universidade de Coimbra



International Federation for Structural
Concrete

Abstracts of the International Workshop

**“Fire Design of Concrete Structures –
From Materials Modelling to Structural Performance”**

University of Coimbra, Portugal

8th and 9th of November 2007

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⊙ KILLING ELEMENTS BASED ON SPALLING RATE (3mm/min) FIRE = AX DURT

- MECHANICAL
- THERMAL
- CREEP

MEE
THERMAL
CREEP
TRANSIENT

FEM
DIFFERENT
SPAWN
TYPES

VARIOUS
PLANS
OF
TUNNEL

SOIL
PROPERTIES

2 nd Day - Morning	
SESSION 5 - Chair - Luc Taerwe, Co-chair - Fernando Branco	
8h 30m - 9h	KEYNOTE SESSION 5 - Venkatesh Kodur - Michigan State University - USA - "MACROSCOPIC FINITE ELEMENT MODELS FOR TRACING THE RESPONSE OF CONCRETE STRUCTURES UNDER FIRE CONDITIONS"
9h - 9h 10m	Takashi Horiguchi - Hokkaido University, Japan - "BENDING STRENGTH AND FRACTURE TOUGHNESS OF HYBRID FIBRE REINFORCED HIGH STRENGTH CONCRETE AT HIGH TEMPERATURE"
9h 10m - 9h 20m	Yahia Msaad - CERIB - Study and Research Center for the Concrete Industry - France - "TEMPERATURE AND SHEAR CAPACITY CALCULATION FOR PRESTRESSED HOLLOW CORE SLABS UNDER FIRE CONDITIONS"
9h 20m - 9h 30m	⊕ KILLING ELEMENTS SPALLING DANGER BY TIME/TEMP Jean-Marc Franssen - University of Liège - Belgium - "NUMERICAL EVALUATION OF THE FIRE BEHAVIOUR OF A CONCRETE TUNNEL INTEGRATING THE EFFECTS OF SPALLING" <small>SOIL STRUCTURE INT.</small>
9h 30m - 9h 40m	Patrick Bamonte - Politecnico di Milano - Italy - "ON THE EFFECTS OF STRUCTURAL STABILITY ON THE M-N ENVELOPES OF THERMALLY-DAMAGED R/C SECTIONS"
9h 40m - 9h 50m	Claudio Pozzi - Ove Arup & Partners - UK - "A NEW RISK-BASED APPROACH TO PREDICT SPALLING OF ORDINARY STRENGTH CONCRETE WALLS SUBJECTED TO FIRE"
9h 50m - 10h	Frank Dehn - Leipzig Institute for Materials Research and Testing - Germany - "INFLUENCE OF TYPE AND AGE OF SYNTHETIC FIBRES ON THE HIGH TEMPERATURE AND FIRE BEHAVIOUR OF CEMENTITIOUS MATERIALS"
10h - 10h 10m	Martin Schneider - Technical University of Vienna - Austria - "COMPARISON OF AN APPROXIMATED METHOD WITH FEM CALCULATIONS FOR THE EVALUATION OF THE FIRE RESISTANCE OF CONCRETE TUNNEL SECTIONS"
10h 10m - 10h 30m	Discussion
10h 30m - 10h 50m	COFFEE BREAK
10h 50m - 11h 20m	KEYNOTE SESSION 6 - Stephen Pessiki - Lehigh University - USA - "CURRENT RESEARCH NEEDS FOR THE FIRE DESIGN OF PRECAST CONCRETE BUILDING STRUCTURES IN U.S. PRACTICE"
11h 20m - 11h 30m	Long Phan - National Institute of Standards and Technology - USA - "PERFORMANCE OF CONCRETE IN FIRE"
11h 30m - 11h 40m	João Paulo Rodrigues - Universidade de Coimbra - Portugal - "BEHAVIOUR OF A FIBRE REINFORCED CONCRETE TUNNEL SEGMENTS SUBMITTED TO FIRE"
11h 40m - 11h 50m	Jeremy Chang - University of Canterbury - New Zealand - "EFFECT OF THE END AND SIDE CONNECTIONS TO THE HOLLOWCORE CONCRETE FLOORING SYSTEMS IN FIRE"
11h 50m - 12h	Fernando G. Branco - Universidade de Coimbra - Portugal - "INFLUENCE OF THE TEMPERATURE ON THE STRENGTH OF SINGLE ADHESIVE ANCHORS UNDER TENSILE LOAD"
12h - 12h 10m	Paulo Piloto - Polytechnic Institute of Bragança - Portugal - "PUSH-OUT TESTS FOR PARTIALLY ENCASED BEAMS AT ELEVATED TEMPERATURE"
12h 10m - 12h 20m	Brian Hardie - Ulster University - UK - "EFFECTS OF ELEVATED TEMPERATURES ON PROPERTIES CONCRETE BLOCKS"
12h 20m - 12h 30m	Ali Nadjai - University of Ulster - UK - "IS A FRP-RC STRUCTURE SAFE ENOUGH IN FIRE?"
12h 30m - 13h	Discussion
13h - 14h 30m	LUNCH

✓
✓
✓
✓
✓
✓
X
IRREVERSIBLE MAT. CONSIDER AFTER HEAT TREATING

⊕ KILLING ELEMENTS
SPALLING
DANGER BY TIME/TEMP

PUSH-OUT TESTS FOR PARTIALLY ENCASED BEAMS AT ELEVATED TEMPERATURE

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Keywords: Elevated temperatures, bond strength, partially encased beams.

EXTENDED ABSTRACT

Partially encased beam is a steel-concrete composite structure, made-up with a hot rolled profile and filled with concrete between flanges. Such structural element improves load-bearing capacity at elevated temperatures.

Bond stress is the key parameter to determine the strength limit state in splitting contact, being represented by the shear stress at steel-concrete interface, which enables both materials to get composite mechanical action, see figure 1.

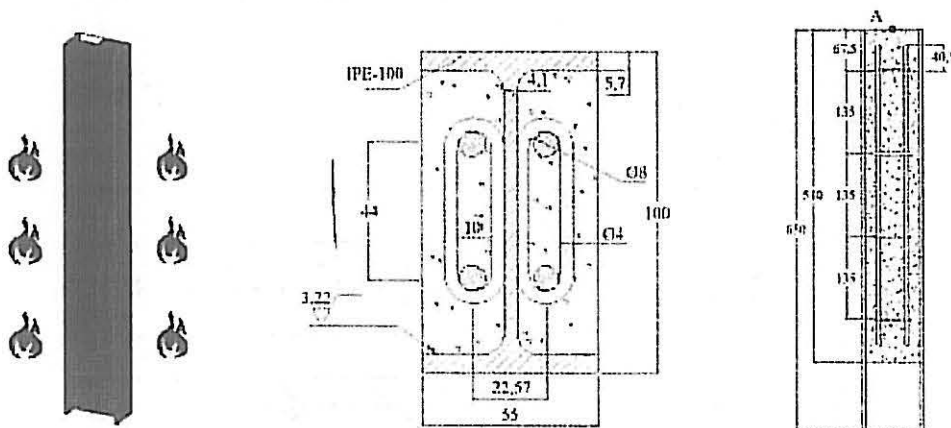


Figure 1 – Model for partially encased beam at elevated temperature.

This work presents an experimental method for testing bond characteristics for partially encased beams at elevated temperature (400 [°C]), which will be useful for the numerical modelling of contact. Contact may be represented by non linear finite spring element, introducing force versus relative displacement between both materials, using geometric and material non linear analysis.

The experimental principle is based on axially load concrete blocks by means of a hydraulic jack, at high temperature level, measuring the relative displacement of concrete, determining the load histogram. A set of three tests were carried out for partially encased beams without welded stirrups.

Specimens were heated at constant heating rate of 400 [°C/h], by means of electro - ceramic resistances, using 70 [kVA] heating power unit, as represented in figure 2. Thermocouples (type K) were used to control heating source and to record temperature inside eight specific points over each partially encased beam (four welded on steel beam and four plated connected to concrete, see figure 3).

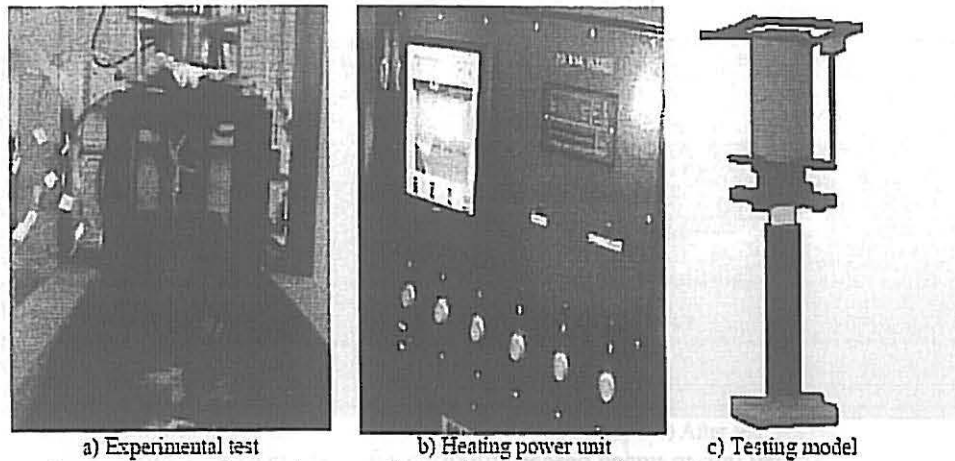


Figure 2 – Experimental set-up for push out tests at elevated temperature.

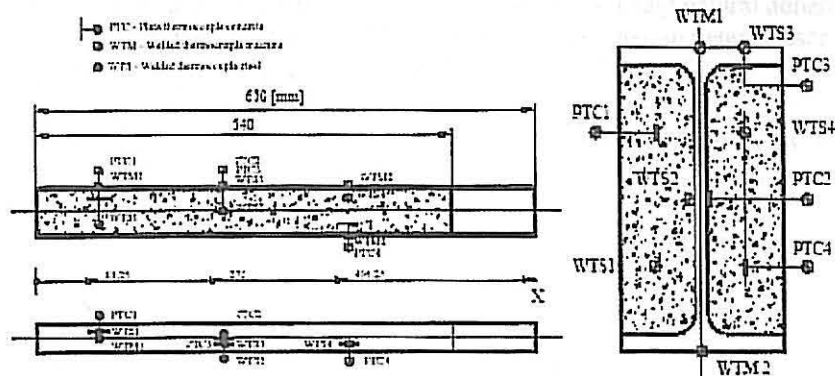


Figure 3 – Thermocouple position on each tested partially encased beam.

Every material was characterized according to national standards [1.2]. Hot rolled profile S275, with 500 [MPa] yield stress and low strength reinforced concrete C12/15, with $\sigma=8$ [mm] B500 bars with ribs. Stirrups are made of cold formed steel with 4 [mm] diameter plain bars with 400 [MPa] yield stress, see figure 1.

Steel surface roughness characterization was determined according to ISO standards [3]. Roughness was measured over 18 evaluation lengths for each beam, producing an average roughness of 3.22 [μm].

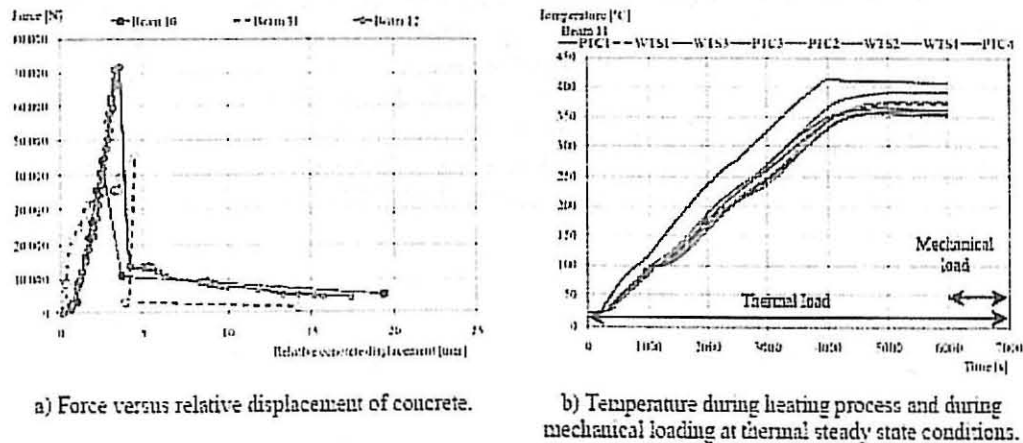
After temperature is stabilized inside beam cross section, an axial load was introduced and incremented in several steps up to the ultimate limit state of concrete blocks (large longitudinal displacement with local concrete failure), see figure 4.

All recorded temperatures present values between 350 [$^{\circ}\text{C}$] and 400 [$^{\circ}\text{C}$], being the steel-concrete interface controlled with thermocouples WTS2, PTC2 and PTC3.



Figure 4 – Push out tests for partially encased beams at 400 [$^{\circ}\text{C}$].

Figure 5 represents the experimental results for all three beams, using natural adherence at high temperature. Displacement was measured by means of wire potentiometer sensor attached to the concrete blocks with an accuracy of 0.1 [mm].



a) Force versus relative displacement of concrete.

b) Temperature during heating process and during mechanical loading at thermal steady state conditions.

Figure 5 – Results for beams with natural adherence at 400 [$^{\circ}\text{C}$].

The maximum shear stress was determined at 400 [°C] for all tests. Differences between force displacement behaviour results for the first two tested beams may be justified by the fact that in the first case both concrete blocks travel at the same time, while in the second case, (beam 11) presents local failure in one block, followed by large concrete displacement. The third test followed measured force displacement of the first test with higher maximum shear stress, see table 1.

Table 1 – Experimental values for bond stress at 400 [°C].

TESTED BEAM	MAXIMUM FORCE [N]	MAXIMUM BOND STRESS [MPa]
Beam 10	44142	0.293
Beam 11	45487	0.301
Beam 12	71689	0.476

The shape of this result agrees with typical bond characteristics for composite sections presented at room temperature, [4]. This shape also agrees with push-out tests recorded at room temperature, [5].

More results are being produced for partially encased beams, at elevated temperature, using stirrups welded to the web steel profile. Different results are expected for bond stress and bond behaviour.

References:

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